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Towards innovation on computer science courses

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***Abstract*— Technologies change very rapidly, and universities need to be increasingly connected to the needs of the industry. With the advent of industry 4.0, the transformations in curricula must be continuous. The current scholar must be a professional future who finds new solutions, who knows how to make a decision based on the data, and who can communicate with different areas. The insertion of entrepreneurship practices towards the development of innovative products in computer courses can academically boost the scholars' characteristics necessary to the today's world, such as teamwork, problem-solving, systemic vision, communication, protagonism, and creativity. A new approach that makes it possible to address the needs of the locality to the surroundings of the educational institution, to highlight the strengths of the scholars in terms of solving such demands, and to propose innovative works strongly linked to the local productive arrangement. The design of the approach follows an innovation framework proposed by Steinbeis University-SIBE, which expands and potentiates the phases of Design Thinking in a larger number of more detailed steps that guide well-defined activities. The results presented by the use of the approach shows that most of the work developed has the potential to become an innovation, which will help in local and regional development.*

I. INTRODUCTION

The way we construct knowledge, in a way, defines us. In other terms, if knowledge is presented in the academy in a fragmented approach, if the curricular elements do not integrate and do not answer to a learning project aimed at the full development of the scholars, it will not be possible to form a whole, integral subject. The fragmentation of scientific knowledge to be taught reveals itself in the disconnection of disciplines at the academy and has been detrimental to education. Even in the context of a given subject, knowledge is separated into some relatively watertight contents, which are presented in a detached and disconnected manner. The effect of the fragmentation of learning to be taught is the loss of meaning, which manifests itself in scholars as a refusal of specific disciplines, showing that they can not understand the connections and associations among the different areas of knowledge.

As critical as the conception of a human being that one wishes to form is to present comprehension of relational knowledge in which the areas of expertise - and their contents, methods, and worldviews - can be perceived with excellent integration. In the area of Education, interdisciplinary [1], multidisciplinary [2], and transdisciplinary [3] proposals are investigated to overcome the fragmentation of the curriculum [4], which, by making the disciplines very technoscientific, ends up creating academy dynamics in which the scholar is responsible for bridges between knowledge, and not the curricula. However how to integrate the curriculum without giving up the several forms of knowledge construction that the areas carry? What do to make learning more meaningful by correlating knowledge with daily life?

For curricular integration to become a reality in the academy, it is necessary that the Political Pedagogical

Project (PPP) states new ways of handling management and collaborative effort among lecturers [5]. One way to do this is to institute practices common to all areas, concerning active teaching and learning methodologies (such as cooperative learning, project learning or research and problem-solving), as involving formative and procedural assessment strategies [6].

Fieldwork, projects, complex problem solving and end-of-course work are cases of integration activities that give purpose to learning, connecting them together and involving scholars and lecturers through proposals that succeed in essential knowledge of fundamental skills that fill the whole curriculum. Group work is an outstanding challenge for all, at any age, and in today's society, it is a relevant and fundamental capacity, which aims to encourage cooperation and foster learning in the coordination of different roles, self-control, articulation, and management of tasks, research, planning, and construction.

This work proposes the inclusion of an innovation framework to support the curricular integration, and contributes to the vocational affirmation of the scholar within the chosen area of action, although providing the development of applications that can reinforce local and regional rise.

This paper is organized as follows: In section II we present a discussion about the difficulties of integrating the curriculum and some literature proposals that try to address such difficulties; In Section III, we present Steinbeis-SIBE innovation framework ans its applicability as a viable solution to such limitations; In section IV we present a real practice combining several disciplines towards innovation projects; In section V we present and discuss the products resulting from such practice; In section VI we end with our conclusions and future work.

II. PROBLEM DESCRIPTION AND RELATED WORK

Nowadays, there is no more place for solely technical education, which only prevailed for the development of specialties - based on the scientific development of knowledge. This path crystallized the academy history marked by the disciplinary fragmentation [7] [8], in a departmental arrangement that crosses the constitutive cycles of the course. Though, this paradigm shift is needed but challenging to accomplish in practice.

Interdisciplinarity rose at the end of the last century from the demand to overcome the fragmentation caused by a positivist epistemology. The sciences were divided into several disciplines, and interdisciplinarity renewed at least dialogue among them. Considered by the science of education as an organic relation of the subject discipline and applied discipline, interdisciplinarity has become an admitted term in the academy because it is seen as a way of thinking.

In this way, interdisciplinarity would be a way of obtaining transdisciplinarity, a stage that would not be in the interaction and interchange between the sciences, but would reach a stage where there would be no more barriers among the disciplines. Currently, interdisciplinarity has been welcomed by most educators, since such a position globally ensures the construction of knowledge, breaking with the boundaries of disciplines because only the integration of content would not be enough.

The logic behind is simple: if reality is a complex and broad one, fragmented education does not consider for understanding it in its entirety, making it as needed as it is essential to exchange and dialogue among disciplines during the process of the meaningfulness of both content of the world in which we live. Additionally, interdisciplinarity reveals precious skills in scholars, such as curiosity, interest in learning, and the ability to work in groups. It leads, at the same time, to significant results in scholars' performance and their development as social beings.

Faced with the progressive globalization of the economy [9], the conditions for the formation of a new professional are emphasized, with flexibility stressed at the expense of specialization. From this, and for safeguarding the flexibility of curricular organization, interdisciplinarity takes strength given the delineation of a new formative pathway. According to this new methodology, several proposals try to address the limitations imposed by the non-integration of the disciplines.

Perhaps it is the most popular among all proposals for integration between disciplines is in the form of project development [10]. In such a model, several disciplines run during the academy year focusing on the development of a process or product that should be ready at the end of the term. Each subject contributes to some of the skill necessary for the development of the processes or products, which can be developed individually by the scholars, or uniquely throughout the class.

However, this type of integration is not something officially regulated, unless it is curricular. Integration of curricular disciplines [11] does not offer the opportunity of not occurring combination, either through projects or any other chosen methodology. This model has given rise to some higher technology courses that do not offer a single formation, but a more general primary formation, and from a certain point, the scholar can choose the formative path to follow, thus selecting a more specific area.

Teaching along with research is also an option that has always worked well in stricto sensu programs and has also been used in secondary and higher education courses [12]. This model lets the scholar to be updated and in line with a specific study object, and to improve their knowledge by taking advantage of the supervision of a specialist lecturer in the chosen area.

A proposal that in addition to being interdisciplinary -- the transdisciplinary -- consists of projects integrated by teams of scholars from different areas and courses [13] [14]. This model expands the possibilities of projects with new ideas because there are many problems of a specific area that researchers in the area alone can not solve. In general, computation has done well this role, being support for the resolution or speed up in solving problems of physics, biology, chemistry, among others.

From the integration of exact sciences emerges the STEM, a movement of integration between Science, Technology, Engineering, and Mathematics. STEM proposals range from projects applied in early childhood education [15] to higher education [16]. The approach involves scholars in hands-on activities that combine different knowledge and lead to creative learning.

III. INNOVATION FRAMEWORK

Based Faced with the challenges of a corporate world, marked by high technology and competitiveness, the development of software products and services needed to keep pace. To this end, so-called agile methods have emerged. Agile Software Development involves a set of methodologies that serve to accelerate the pace of software development processes [17].

With its origin dating back to the mid-1990s, the Agile concept was soon spread among the experts, which resulted in the creation of different models that support project management. The reason agile methods suggest is to address traditional development models, which are slow and bureaucratic, to reduce the development cycle in weeks or months - in conservative models this cycle can last for years.

Therefore, assuming that the projects have a defined beginning and end, and that they are planned and developed in stages, some of the main characteristics - besides agility - of the agile methods are incremental process (almost an antithesis of the traditional cascade model) , customer collaboration, adaptability (each project is subject to various modifications), simplicity, constant feedback, small teams (but with a high technical level).

Several frameworks that support the agile methodology have been created, and we can mention the main methods: Feature Driven Development (FDD) [18], Extreme Programming (XP) [19], Microsoft Solutions Framework (MSF) [20], Dynamic System Development Model (DSDM) [21], and Scrum [22].

FDD's [18] basic premise is the focus on functionality, which allows the project team to perform incremental planning. This type of action helps to give agility to the development of solutions in environments of extreme uncertainty, where changes are inevitable. FDD programming starts with the business overview since this method considers the sum of everything more important than each of the parts separately. We then proceed to the detailing of the product with the subdivision by areas to be modeled, culminating in the description of each function.

XP [19] is an agile method focused on software development based on three pillars: agility in the development of the solution, resource saving and quality of the final product. In order to achieve excellence in the services provided, an XP team must be values-based, that is, a contract of attitudes and behaviors that lead to success. These behaviors and attitudes guide the actions of the XP team in each activity to be performed, ensuring the integration and synergy necessary for good performance. In addition to the values, the agile XP method also takes into account better working practices, which aim to ensure the effectiveness of the XP team's work, as well as customer satisfaction throughout the development process.

MSF [20] is one of the agile methods most used for the development of technological solutions by small teams, focusing on reducing risks to the business and increasing the quality of the final product. The purpose is to identify the most common flaws in technology projects, mitigating them and improving the success rates of each initiative.

DSDM [21] is one of the oldest agile methods used not only in project development but also in technology. A little different from the other agile methods, it is aimed at the development of projects with a fixed budget and short deadlines, taking into consideration that the client has no way of knowing how much the final solution will cost. Among its best practices are incremental and iterative development, a collaboration between client and team, and integration of functionalities, which we also see in other agile methods. It is worth noting that DSDM differs from other agile methods in its structure, which is composed of interconnected processes of modeling, design, construction, and implementation, as well as time management, which is not flexible until the functionalities change, but since that the deadlines for implementation remain the same.

Scrum [22] is the most widely used agile method today, especially since it can be easily integrated with other agile methods, applying not only to software development but also to any work environment. With a focus on project management, Scrum is based on iterative and incremental planning, which occurs, as explained, by the meetings known as Sprints - this time we will approach the concept in detail. It reiterates, from the beginning of the project, the list of functionalities to be developed - practice also called, in this case, product backlog. In the process progress, each feature becomes a Sprint, whose details to be created and developed go from the product backlog to the sprint backlog. From the sprint backlog, the activities are distributed among the members of the Scrum Team, who must develop them within a deadline that usually takes no more than four weeks. At the end of each sprint, the sprint review meeting, an alignment meeting on what was delivered, is held. From there, you begin to plan the next sprint. These steps happen in succession until the final product is ready for delivery.

In addition to these already established methodologies, an approach has been taking place. Design Thinking [23] is a way of the approach taken from the field of design and tailored to companies and corporations. Design Thinking is seen as a set of practices and processes, a method that proposes a new approach to problems. This is related to obtaining information, its analysis and the resulting solutions offered from the generated knowledge. The focus becomes the experience of the consumer or the target audience, in the search for answers to the problems found through Design Thinking as a methodological approach. The significant difference of this method is that it starts from the solution, from the project, and not necessarily from all the parameters of the problem, as is common in the scientific method. The steps assigned to design thinking are immersion, ideation, prototyping, and development. The process, from immersion to development, seeks innovation in a non-linear way, the attribution and discovery of new values and meanings for projects, services and products , as well as the constitution of integrative thinking as a tool to reach solutions, not exactly definitive, but holistic and based on the experience of the consumer.

The framework proposed by the Steinbeis School of International Business and Entrepreneurship (SIBE - https://sibe-edu.com) consists of joining the best practices of most frameworks based on agile methods. The Figure 1 shows the life cycle of such a framework.

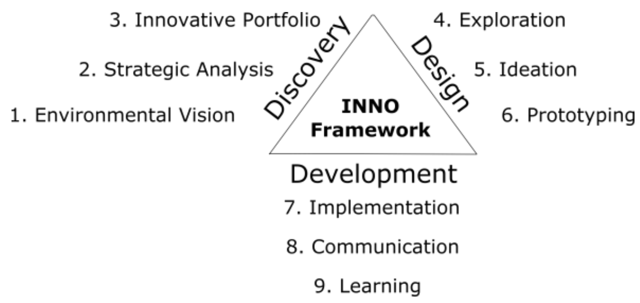

Fig.1: Steinbeis-SIBE Innovation Framework.

It consists of an expansion of design thinking to define the focus of the products to be developed, as well as to define all phases of the project. Also, it uses Scrum sprints for each new phase, active collaboration between client and development team like DSDM, performs risk analysis like MSF, and performs small deliveries like PDD and XP. This framework is divided into three dimensions: discovery, design, and development. The discovery dimension includes the phases of environmental vision, strategic analysis, and innovation portfolio. The design dimension consists of the exploration, ideation, and prototyping phases. And the development dimension consists of implementation, communication, and learning phases. For each phase, a specific tool was used.

IV. INTEGRATED PROFESSIONAL PRACTICE

The Integrated Professional Practice (IPP) consists of a teaching methodology that proposes to ensure space and time at the curriculum, allowing the connection between the knowledge built in the different disciplines of the course and the real world. In this way, it is possible to customize the curriculum and expand the dialogue between different areas of activity.

Currently, it is a practice widely disseminated and implemented in institutions of vocational education, being an important piece for the development of practical activities correlated to the course [24]. In one course of the computing area, the objective of IPP is to search for theoretical and practical knowledge to base the choice of the discipline that will be developed, and providing the scholars to combine the concepts studied daily with the practice, predicting their professional use.

Therefore, it is evident that the IPP has as its focus the overcoming of curriculum fragmentation [25] and the search for a curriculum that makes sense and meaning to the scholar. It is possible to highlight in this practice the intention to operationalize the vertical integration of the curriculum, providing unity throughout the course, comprising a logical sequence and an increasing deepening of the knowledge in contact with the actual work practice, constituting as a permanent space of reflection-action involving the entire faculty of the course in its planning.

IPP is strongly influenced by the STEM learning [26] [27], where the original idea is to unite knowledge of these four areas around the construction of something that solves the proposed challenge. STEM works in the form of creative workshops so that scholars in groups can solve some challenge practically. The main thing is that it is a practical challenge that requires knowledge from different areas.

In this work, we present an IPP that takes into account an entire innovation framework to define the fields of action of future projects to be implemented. We believe that inventions that solve local problems have a more significant potential to become an innovation, allowing an improvement in the quality of life of such a community. The IPP was proposed through the integration of three disciplines: (i) technological innovation, (ii) prototyping of hardware and software, and (iii) development of mobile applications.

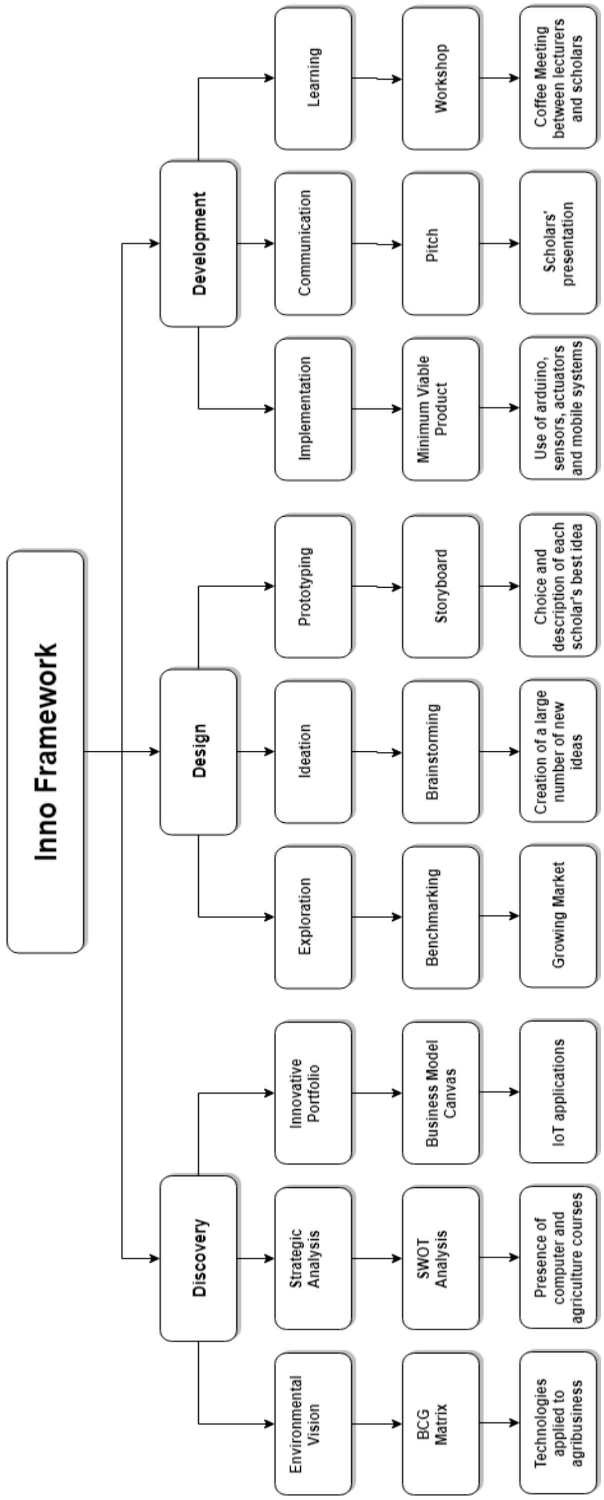

Fig. 2: Steinbeis-SIBE Innovation Framework.

The discipline of technological innovation consists of working concepts and practices focused on innovation through technical products applied to local and regional development. Figure 2 presents all the dimensions, their phases, tooling, and the result. The framework is divided into three dimensions. Each dimension is divided into three phases. Each phase presents main objectives and some findings.

The results showed in Figure 2 demonstrated that our campus is located in a region that has a robust agricultural vocation and that our university offers courses and counts on specialists in the farming and computing areas. This set of factors guided the work of IPP to the Internet of Things (IoT) applications [28], as it is a paradigm that can bring together all the areas addressed towards local and regional development.

The discipline of prototyping of hardware and software consists of developing hardware and software solutions that can be prototyped in a small electronics lab through inexpensive, easy-to-implement opensource platforms. Proposed projects used Arduino (or some of its variants) [29], which consists of a board with a microcontroller and some complementary components that aims to facilitate the development of projects for reading electronic sensors and actuators, besides some expansion modules.

The discipline of development of mobile applications [30] consists of learning technical knowledge about the Android Software Development Kit (SDK) architecture, library features, besides good practices for mobile programming apps. The majority of the lectures are focused on the practical aspect, developing and deploying smartphones applications. Also, we developed a final software product for Android mobile devices that communicate with the Arduino through data communication modules (such as WiFi), and allow the reading of values coming from the sensors and manipulation of the actuators. Internally, Arduino uses a variant of the C language, but for development on Android mobile devices, we used Java programming language.

Therefore, the integration among the three disciplines occurred as follows: in the innovation class, the scholars defined their potential in developing new products aligned with the needs of the local productive arrangement (LPA). They participated in a creative process that resulted in one idea per scholar, which solves one of the limitations investigated in the LPA. Each of the solutions was prototyped and implemented in conjunction with the two technical disciplines. The products generated were presented to an interdisciplinary committee and had their potential evaluated. It was a moment of learning and socialization of knowledge, ensuring a space destined for the focus of professional training, constituting a moment of reflection, which encouraged research and promoted interdisciplinarity.

V. RESULTS AND DISCUSSION

Agriculture, livestock, and aquaculture are a source of subsistence for a large part of the rural population who maintain small and medium-sized farms and produce agricultural products for their consumption and sale to the urban population. The outcomes of these segments consist of an essential source of income and employment for the field, usually performed by teams formed from a family unit. The data show that this economic activity is present in 85\% of rural properties in Brazil, and 70\% of the food consumed in the country is produced through this segment, the southern region of Brazil is the second largest producer (http://www.fao.org). This is the scenario that our research is established, and it was pointed out by the mechanisms of the innovation framework.

After defining each scholar's research theme, the prototypes to be developed were established, and are listed below:

- Automatic feeder for fish: the region is a major producer of fish in confined tanks. In most, the feeding is carried out manually. The proposal implemented an electro-mechanical device, which at predefined hours of the day, pour in the water of the tank an amount of fish feed.
- Automated greenhouse: several small producers keep greenhouses for the production of vegetables. Factors such as humidity and temperature should be controlled. The proposal implemented moisture and temperature sensors that drive greenhouse cooling devices when minimum and maximum limits are reached.
- \A system of automation of irrigation of the soil: the region maintains a strong vocation concerning the production of grains. Grain crops, especially rice, need a layer of water to develop. The control of this layer of water is usually done manually. The proposal implemented through depth sensors dispersed in the plantation, a monitor in the opening of the siphons that allow managing the amount of water to be scattered in the plantation.
- System for detecting carbon monoxide and flammable gases: industries must control the amount of carbon monoxide in order to maintain the health of their employees. This proposal implemented through gas sensors, an alert for high levels of carbon monoxide.
- System for the control of entrance or exit of people: several institutions must control the presence of its employees. The proposal implemented radio

frequency identification cards to manage entry and exit of employees on an electronic point card.

- Lighting control system for studios: home automation is an area that automates the management of electrical and mechanical devices in homes. The proposal implemented a centralized control of lights and appliances so that the owner of the residence can trigger any device through only one interface.
- Checking for spinal problems: Spinal problems such as lordosis, kyphosis, and scoliosis are quite common these days. The proposal implemented through a range of positioning sensors, a device that can generate a 3D image of a person's column, and show the type of curvature of the column and its degree.

The driver devices were developed in the discipline of prototyping of hardware and software, and the user interface was developed in the discipline of development for mobile devices. Therefore, all prototypes can be controlled or display reports to users through mobile applications developed by scholars. It makes all proposed solutions more dynamic and up-to-date, and attractively presented to future investors.

Such prototypes were presented to a group of researchers and evaluated regarding innovation potential. From now on, these jobs will pass through investor, and the chosen ones will become startups who can develop their products for the productive market. Therefore, what started as an IPP may have fostered the entrepreneurial spirit in scholars, to the point that when they graduate in the graduation course, they already have their companies selling their products.

VI. CONCLUSION

The organization of scholarly knowledge by disciplines a few years ago has been the point of criticism ranging from the argument that disciplines represent more of an outcome to education than to social, cultural and political issues, underpinning the educational policies that guide the organization of academy curricula. However, the main criticism of the curricular disciplinary approach is the fragmentation of knowledge. Among the alternative proposals to the organization of academy knowledge by disciplines, those that focus on interdisciplinarity and curricular integration stand out.

This traditionally fragmented model does not lead to the rise of innovation. An environment conducive to innovation is one in which there is a clash of ideas. People of various experiences and specialties must be present in the process of creation, and these moments of creation must be structured to produce results. Another point of stimulus to diversity is the possibility that exchanges occur in any direction, be it between peers and between people from very different areas. An innovative environment was proposed and supported by IPP.

Interdisciplinarity via IPP can materialize in teaching methodologies, curriculum, and teaching practice. From the historical perspective that reveals that the process of fragmentation of knowledge is accentuated with the process of fragmentation of work, one must be aware that forms of work organization, which do not focus on completeness, can emphasize the fragmentation of school knowledge.

IPP allowed several issues to be addressed. Approaching the campus with LPA, one of the missions of higher education institutions, which consists of developing the region in which the campus is located. Scholars experienced a real-world innovation environment, ranging from a vision of open product development opportunities, designing solutions to prototyping. Also, they have experienced the most current development methodologies, such as design thinking, agile methods, and project management. Finally, each scholar has a finished product with potential patent registration, and the possibility of opening a startup aimed at marketing such a product.

Besides, IPP understands different situations of experience, learning, and work, guided by research as a pedagogical principle, whose purpose is to articulate knowledge through the integration of the disciplines in the course and to bring the training of scholars closer to the world of work.

As future work, the products will be presented in rounds of investors, to capture resources and boost the creation of startups. Regarding teaching, the practice of IPP will be adopted as a complementary activity to the scholar's education, in a continuous and absorbed by the current curriculum of the technology courses.

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